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ABSTRACT

The "Chemistry Card Game" for teaching stoichiometry of inorganic precipitation and ionic complex reactions is described in the first article of this UNESCO newsletter. The game is played with 106 cards consisting of 19 kinds of cations, 14 kinds of anions, and one kind of molecules (NH3). Included are the instructions for making the cards, rules for playing, a list of reactions valid in the game, and a table of solubility products and instability constants. Instructions are provided for assembling a kit of chemicals for testing reactions other than those stated in the list of reactions, in trying to improve the effectiveness of using the cards. The remaining three articles describe an adaptation of an O-Level Nuffield Chemistry Stage I experiment with oxygen, an experiment utilizing the displacement reaction between Ag2CrO4 and KI, and curriculum reform activities in Indonesia. (PR)

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UNESCO

CHEMISTRY TEACHING PROJECT IN ASIA

NEWSLETTER

VOLUME 3, NUMBER 1

AUGUST, 1969

P.O. BOX 1425
BANGKOK, THAILAND

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The Unesco Project for Chemistry Teaching in Asia

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CHEMISTRY CARD GAME - WHAT IS IT?

Chemistry teaching is not merely conveying knowledge of subject matter to the students. We have to consider both knowledge and methods in teaching this branch of science. Various channels can be used to implant new ideas, but the problem is: which one is more effective? We are not going to discuss all sorts of chemistry teaching methods which are now used in our Asian countries' High Schools; nor are we going to mention those methods used outside this area. Yet, new methods must be discovered. This article is only to give you a suggestion in teaching stoichiometry of inorganic precipitation and ionic complex reactions.

We have succeeded in using playing cards as visual aid for this purpose; we call the game, tentatively, Chemistry Card Game.

We are aware that, there is a certain limit in using the cards as teaching aid. The number of the cards and the kinds of cations and anions we select, cannot embrace all compounds of those types of reaction.

As the game is intended for High School students, we also try to avoid complicated reactions which can confuse the players.

We have also set up a chemistry kit which can be used by the students to test those reactions appearing in the game, - by doing so we hope that the game is not just for amusement, but rather, that many things can be studied. Discussion among the players is open during the play. Chemistry teachers can do much in conducting such a discussion.

About the cards

1. There are 106 cards consisting of 19 kinds of cations, 14 kinds of anions, and 1 kind of molecule (NH_3). We include 3 kinds of ions which are familiar to the students, even though they cannot be used either to precipitate or to form complex ions, i.e. K^+, Na^+, and NO_3^-.

2. List of the cards

Symbols and Coefficients	Number of the Cards	Symbols and Coefficients	Number of the Cards
Ag^+	3	Cu^{2+}	3
$3Ag^+$	1	Fe^{2+}	2
Al^{3+}	2	Fe^{3+}	3
Ba^{2+}	2	Hg^{2+}	2
$3Ba^{2+}$	1	K^+	1
Ca^{2+}	2	Mg^{2+}	2
$3Ca^{2+}$	1	$3Mg^{2+}$	1
Cd^{2+}	3	Mn^{2+}	2
Co^{2+}	2	$3Mn^{2+}$	1
Cr^{3+}	3	Na^+	1

Symbols and Coefficients	Number of the Cards	Symbols and Coefficients	Number of the Cards
Ni^{2+}	3	$6F^{-}$	1
Pb^{2+}	3	I^{-}	2
Sr^{2+}	2	$2I^{-}$	2
$3Sr^{2+}$	1	$4I^{-}$	1
Zn^{2+}	3	NO_3^{-}	1
AsO_4^{3-}	2	OH^{-}	2
Br^{-}	2	$2OH^{-}$	2
$4Br^{-}$	2	$3OH^{-}$	1
Cl	2	$4OH^{-}$	1
$4Cl^{-}$	2	PO_4^{3-}	2
CN^{-}	2	$2PO_4^{3-}$	1
2CN	2	S^{2-}	5
4CN	1	SCN^{-}	2
$6CN^{-}$	1	$4SCN^{-}$	1
CO_3^{2-}	4	SO_4^{2-}	3
$C_2O_4^{2-}$	3	$2NH_3$	3
F^{-}	2	$6NH_3$	1

Total Number of the cards : 106

3. Each symbol of the cation, anion and molecule is put in the centre of the card.

4. Size: 5 cm x 8 cm

5. Value: each card has a value which is denoted by a numeral :

Cations at the left corner (below)
Anions at the right corner (below)
Ammonia at the middle (below)

6. For more effective use of the cards, we put smaller symbol (and the coefficients) of each cation, anion, and molecule at the left upper corner. For clarity, see Fig. 1,2,3.

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Fig. 1

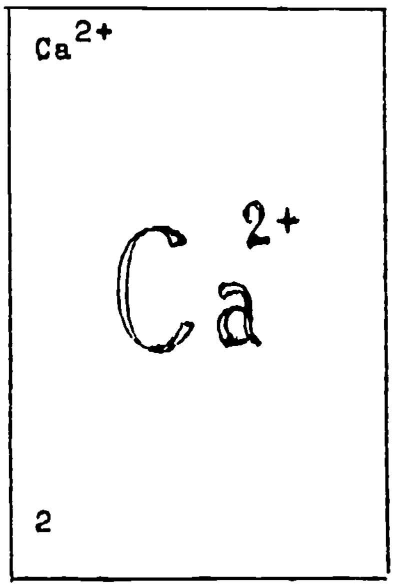


Fig. 2

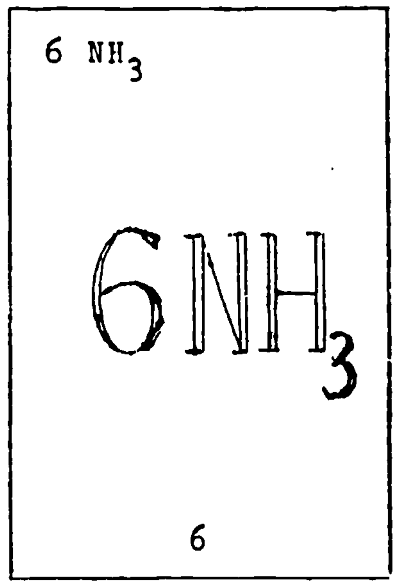
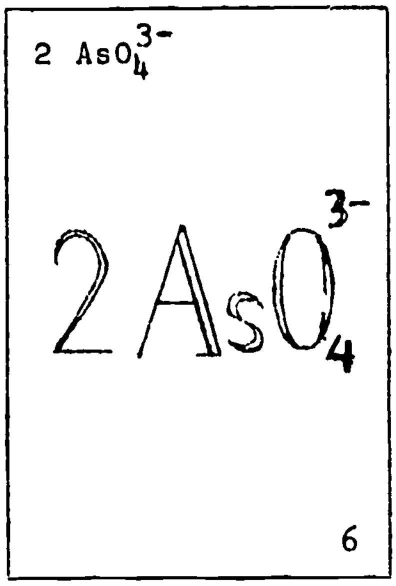


Fig. 3



Rules of the game

1. The game can be best played by 2,3 or 4 persons.

2. Shuffle the cards thoroughly, and put the pack facing down on the table.

3. Each player takes 1 card (beginning with the player who shuffles the cards, round clock-wise), and opens the card.

4. The player who gets the earliest alphabetical letter(s), or, in case players getting the same alphabetical letter(s), the player having the smallest co-efficient, will play first.

5. The first player re-shuffles and distributes the cards, beginning to the left.

6. Each player gets 10 cards.

7. The rest of the cards is put facing down on the table.

8. The first player throws one card on the table. Actually throwing more than one cards with the <u>same symbols</u> is permissible.

9. The second player must throw one card (or more), to precipitate the cation(s) or anion(s) on the table, or to form complex ion(s). The game is limited to

precipitation and ionic complex formation only, when one type of cation reacts with only one type of anion.

10. The next player should throw the card(s) so that:

    (a) if there is precipitate on the table, change(s) the precipitate into complex ion

    (b) if there is complex ion on the table, change(s) the complex ion into precipitate

    The changes can be done by throwing card(s) of

    (a) one type of anion only, or one type of anion plus combination of cation and anion exactly the same as on the table (see example)

    (b) ammonia molecules

    Ammonia is valid for complex formation only.

11. Each player must always have a compliment of 10 cards by taking card(s) from the pack after each discard. This must be done until all the pack of the cards is finished

12. Each player has the right to "pass" and give the turn to the next player.

13. One trick is finished, if no player can do anything to change the compound on the table. The winner of a trick is the last player who throws the card(s).

14. The winner of a trick collects the cards and is credited the points and then leads the next round.

15. The game is over, if a player collects the last trick.

16. Card(s) remained unplayed, when the game is over, is (are) considered as debt, and must be payed from the collection.

17. The winner of the game is the player who collects the highest score.

Example 1. (played by 4 persons)

First player	Second player	Equation	Result
Ag^+ 1	Cl^- 1	$Ag^+ + Cl^- \rightleftharpoons AgCl$	Ag^+ 1, Cl^- 1

Third Player	Equation	Result
$2NH_3$ 2	$AgCl + 2NH_3$ $\rightleftharpoons$ $Ag[NH_3]_2^+ + Cl^-$	Ag^+ 1 · Cl^- 1 · $2NH_3$ 2
Fourth Player	**Equation**	**Result**
"Pass"	No Change	No change
First Player	**Equation**	**Result**
I^- 1	$Ag[NH_3]_2^+ + I^-$ $\rightleftharpoons$ $AgI + 2NH_3$	Ag^+ 1 · Cl^- 1 I^- 1 · $2NH_3$ 2

If the other 3 players say "pass", the trick is over. As this is the final step, the First Player wins the trick [(1 + 1 + 1 + 2) points = 5 points. See note 1]

Notes

1. It is not impossible that the First Player (who wins the play until this stage) converts the compound like this:

First Player	Equation	Result
CN^- 1 CN^- 1	$AgI + 2CN^- \rightleftharpoons [Ag(CN)_2]^- + I^-$	Ag^+ 1, Cl^- 1, $2NH_3$ 2 CN^- 1, CN^- 1, I^- 1

Which opens an opportunity to the players to continue the play; so:

Second Player	Equation	Result
Ag^+ 1 $2CN^-$ 2 S^{2-} 2	$2[Ag(CN)_2]^- + S^{2-} \rightleftharpoons Ag_2S + 4CN^-$	Ag^+ 1, Ag^+ 1, S^{2-} 2 CN^- 1, $2CN^-$ 2, I^- 1 CN^- 1, $2NH_3$ 2, Cl^- 1

2. The Second Player possesses Ag^+ and S^{2-} from the first distribution. After taking one card ($2CN^-$) from the pack (replacement of the first discard), the Second Player now has the opportunity to throw the combination cards of Ag^+, $2CN^-$, and S^{2-}.

3. As Ag_2S is very stable and cannot be converted into any soluble complex ion, the stage is considered as the final one, and it is the Second Player who wins the trick NOT the First (see Note 1).

4. So the Second Player collects (1+1+2+1+1+1+2+1+2) points = 12 points.

Example 2

First Player	Second Player	Equation	Result
$2OH^-$ 2	Fe^{2+} 2	$2OH^- + Fe^{2+} \rightleftharpoons Fe(OH)_2$	Fe^{2+} 2; $2OH^-$ 2

Third Player	Equation	Result
$4CN^-$ 4; $2CN^-$ 2	$Fe(OH)_2 + 6CN^- \rightleftharpoons [Fe(CN)_6]^{4-} + 2OH^-$	Fe^{2+} 2; $4CN^-$ 4; $2CN^-$ 2; $2OH^-$ 2

The trick is over, and the Third Player collects (2+4+2+2) points = 10 points, as $[Fe(CN)_6]^{4-}$ is very stable complex ion.

Example 3

First Player	Other Players	Equation	Result
NO_3^- 1	"Pass"	None	NO_3^- 1

The trick is over, and the First Player collects 1 point.

Example 4

First Player	Second Player	Third Player	Equation	Result
S^{2-} 2 S^{2-} 2	"Pass"	Hg^{2+} 2 Hg^{2+} 2	$2Hg^{2+} + 2S^{2-} \rightleftharpoons 2HgS$	Hg^{2+} 2 S^{2-} 2 Hg^{2+} 2 S^{2-} 2

The trick is over, and the Third Player collects (2+2+2+2) points = 8 points

Questions

1. In example 1, the Second Player throws Ag^+ and S^{2-} at his third turn (first turn he throws Cl^-, second turn he says "pass"), actually he can also throw Ag^+ and S^{2-} at his first turn, after the First Player throws Ag^+. Can you explain why he prefers delaying of throwing those cards?

2. In example 4, the First Player throws 2 cards of S^{2-}. What is his aim of throwing two cards, instead of one?

3. According to rule 15, the game is over if a player collects the last trick.

   Suppose the First Player throws his last card, but the Fourth Player (who still has 3 cards in his hand) wins the trick. Shall the game finish here? (Hint: see rule 1).

Assumption and Limitation

1. All cations are supposed to be in ionized form in the solution.

2. All solutions used are in the same strengths, so that the reactions occur between the reactants are stoichiometrically balanced. All reactions are carried out at room temperature.

3. Hydroxyl ions (OH^-) are used as reactants, and not as medium changers.

4. Ammonia (NH_3) is considered as neutral molecule, and used for complex formation only.

   We avoid such a reaction:

$$2Cl^- + Hg^{2+} + NH_3 \rightleftharpoons HgNH_2Cl + HCl$$

5. We include tables of solubility products and instability constants, as reference for the players, but to avoid arguing among the players, only those reactions written below are valid in the game.

REACTION EQUATIONS

1. Silver Ion, Ag^+

$$3Ag^+ + AsO_4^{3-} \rightleftharpoons Ag_3AsO_4$$
$$Ag_3AsO_4 + 6NH_3 \rightleftharpoons 3[Ag(NH_3)_2]^+ + AsO_4^{3-}$$
$$Ag_3AsO_4 + 6CN^- \rightleftharpoons 3[Ag(CN)_2]^- + AsO_4^{3-}$$
$$Ag^+ + Cl^- \rightleftharpoons AgCl$$
$$AgCl + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+ + Cl^-$$
$$AgCl + 2CN^- \rightleftharpoons [Ag(CN)_2]^- + Cl^-$$
$$Ag^+ + Br^- \rightleftharpoons AgBr$$
$$AgBr + 2CN^- \rightleftharpoons [Ag(CN)_2]^- + Br^-$$
$$[Ag(NH_3)_2]^+ + Br^- \rightleftharpoons AgBr + 2NH_3$$

$Ag^+ + I^-$	$\rightleftharpoons$	AgI
$[Ag(NH_3)_2]^+ + I^-$	$\rightleftharpoons$	$AgI + 2NH_3$
$AgI + 2CN^-$	$\rightleftharpoons$	$[Ag(CN)_2]^- + I^-$
$2Ag^+ + CO_3^{2-}$	$\rightleftharpoons$	Ag_2CO_3
$Ag_2CO_3 + 4NH_3$	$\rightleftharpoons$	$2[Ag(NH_3)_2]^+ + CO_3^{2-}$
$Ag_2CO_3 + 4CN^-$	$\rightleftharpoons$	$2[Ag(CN)_2]^- + CO_3^{2-}$
$Ag^+ + CN^-$	$\rightleftharpoons$	$AgCN$
$AgCN + CN^-$	$\rightleftharpoons$	$[Ag(CN)_2]^-$
$Ag^+ + 2CN^-$	$\rightleftharpoons$	$[Ag(CN)_2]^-$
$2Ag^+ + CrO_4^{2-}$	$\rightleftharpoons$	Ag_2CrO_4
$Ag_2CrO_4 + 4NH_3$	$\rightleftharpoons$	$2[Ag(NH_3)_2]^+ + CrO_4^{2-}$
$Ag_2CrO_4 + 4CN^-$	$\rightleftharpoons$	$2[Ag(CN)_2]^- + CrO_4^{2-}$
$3Ag^+ + PO_4^{3-}$	$\rightleftharpoons$	Ag_3PO_4
$Ag_3PO_4 + 6CN^-$	$\rightleftharpoons$	$3[Ag(CN)_2]^- + PO_4^{3-}$
$2Ag^+ + 2OH^-$	$\rightleftharpoons$	$Ag_2O + H_2O$
$Ag_2O + H_2O + 4NH_3$	$\rightleftharpoons$	$2[Ag(NH_3)_2]^+ + 2OH^-$
$Ag_2O + H_2O + 4CN^-$	$\rightleftharpoons$	$2[Ag(CN)_2]^- + 2OH^-$
$Ag^+ + SCN^-$	$\rightleftharpoons$	$AgSCN$
$2Ag^+ + S^{2-}$	$\rightleftharpoons$	Ag_2S
$2[Ag(NH_3)_2]^+ + S^{2-}$	$\rightleftharpoons$	$Ag_2S + 4NH_3$
$2[Ag(CN)_2]^- + S^{2-}$	$\rightleftharpoons$	$Ag_2S + 4CN^-$

2. <u>Aluminium Ion, Al^{3+}</u>

$Al^{3+} + 3OH^-$	$\rightleftharpoons$	$Al(OH)_3$
$Al(OH)_3 + OH^-$	$\rightleftharpoons$	$[Al(OH)_4]^-$
$Al^{3+} + 4OH^-$	$\rightleftharpoons$	$[Al(OH)_4]^-$
$Al^{3+} + PO_4^{3-}$	$\rightleftharpoons$	$AlPO_4$
$AlPO_4 + 4OH^-$	$\rightleftharpoons$	$[Al(OH)_4]^- + PO_4^{3-}$
$Al^{3+} + AsO_4^{3-}$	$\rightleftharpoons$	$AlAsO_4$
$AlAsO_4 + 4OH^-$	$\rightleftharpoons$	$[Al(OH)_4]^- + AsO_4^{3-}$
$AlAsO_4 + 6F^-$	$\rightleftharpoons$	$[AlF_6]^{3-} + AsO_4^{3-}$

3. <u>Barium Ion, Ba^{2+}</u>

$3Ba^{2+} + 2AsO_4^{3-}$	$\rightleftharpoons$	$Ba_3(AsO_4)_2$
$Ba^{2+} + CO_3^{2-}$	$\rightleftharpoons$	$BaCO_3$
$Ba^{2+} + CrO_4^{2-}$	$\rightleftharpoons$	$BaCrO_4$
$3Ba^{2+} + 2PO_4^{3-}$	$\rightleftharpoons$	$Ba_3(PO_4)_2$
$Ba^{2+} + SO_4^{2-}$	$\rightleftharpoons$	$BaSO_4$

4. Calcium Ion, Ca^{2+}

$3Ca^{2+} + 2AsO_4^{3-} \rightleftharpoons Ca_3(AsO_4)_2$

$Ca^{2+} + CO_3^{2-} \rightleftharpoons CaCO_3$

$Ca^{2+} + 2F^- \rightleftharpoons CaF_2$

$3Ca^{2+} + 2PO_4^{3-} \rightleftharpoons Ca_3(PO_4)_2$

5. Cadmium Ion, Cd^{2+}

$Cd^{2+} + 2OH^- \rightleftharpoons Cd(OH)_2$

$Cd(OH)_2 + 4NH_3 \rightleftharpoons [Cd(NH_3)_4]^{2+} + 2OH^-$

$Cd^{2+} + CO_3^{2-} \rightleftharpoons CdCO_3$

$CdCO_3 + 4CN^- \rightleftharpoons [Cd(CN)_4]^{2-} + CO_3^{2-}$

$CdCO_3 + 4NH_3 \rightleftharpoons [Cd(NH_3)_4]^{2+} + CO_3^{2-}$

$3Cd^{2+} + 2AsO_4^{3-} \rightleftharpoons Cd_3(AsO_4)_2$

$Cd_3(AsO_4)_2 + 12NH_3 \rightleftharpoons 3[Cd(NH_3)_4]^{2+} + 2AsO_4^{3-}$

$Cd_3(AsO_4)_2 + 12CN^- \rightleftharpoons 3[Cd(CN)_4]^{2-} + 2AsO_4^{3-}$

$Cd^{2+} + 4NH_3 \rightleftharpoons [Cd(NH_3)_4]^{2+}$

$Cd^{2+} + 4CN^- \rightleftharpoons [Cd(CN)_4]^{2-}$

$Cd^{2+} + S^{2-} \rightleftharpoons CdS$

$[Cd(NH_3)_4]^{2+} + S^{2-} \rightleftharpoons CdS + 4NH_3$

$[Cd(CN)_4]^{2-} + S^{2-} \rightleftharpoons CdS + 4CN^-$

6. Cobalt (II) Ion, Co^{2+}

$3Co^{2+} + 2AsO_4^{3-} \rightleftharpoons Co_3(AsO_4)_2$

$Co^{2+} + CO_3^{2-} \rightleftharpoons CoCO_3$

$Co^{2+} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+}$

$Co^{2+} + 2OH^- \rightleftharpoons Co(OH)_2$

$Co(OH)_2 + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + 2OH^-$

$Co^{2+} + S^{2-} \rightleftharpoons CoS$

$CoCO_3 + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + CO_3^{2-}$

$[Co(NH_3)_6]^{2+} + S^{2-} \rightleftharpoons CoS + 6NH_3$

7. Chromium (III) Ion, Cr^{3+}

$Cr^{3+} + AsO_4^{3-} \rightleftharpoons CrAsO_4$

$CrAsO_4 + 4OH^- \rightleftharpoons [Cr(OH)_4]^- + AsO_4^{3-}$

$Cr(OH)_3 + OH^- \rightleftharpoons [Cr(OH)_4]^-$

$Cr^{3+} + 3OH^- \rightleftharpoons Cr(OH)_3$

$Cr^{3+} + 4OH^- \rightleftharpoons [Cr(OH)_4]^-$

$Cr^{3+} + PO_4^{3-} \rightleftharpoons CrPO_4$

$CrPO_4 + 4OH^- \rightleftharpoons [Cr(OH)_4]^- + PO_4^{3-}$

8. Copper(II) Ion, Cu^{2+}

$3Cu^{2+} + 2AsO_4^{3-} \rightleftharpoons Cu_3(AsO_4)_2$

$Cu_3(AsO_4)_2 + 12NH_3 \rightleftharpoons 3[Cu(NH_3)_4]^{2+} + 2AsO_4^{3-}$

$Cu^{2+} + CrO_4^{2-} \rightleftharpoons CuCrO_4$

$CuCrO_4 + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + CrO_4^{2-}$

$Cu^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+}$

$3Cu^{2+} + 2PO_4^{3-} \rightleftharpoons Cu_3(PO_4)_2$

$Cu_3(PO_4)_2 + 12NH_3 \rightleftharpoons 3[Cu(NH_3)_4]^{2+} + 2PO_4^{3-}$

$Cu^{2+} + 2OH^- \rightleftharpoons Cu(OH)_2$

$Cu(OH)_2 + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 2OH^-$

$[Cu(NH_3)_4]^{2+} + S^{2-} \rightleftharpoons CuS + 4NH_3$

$Cu^{2+} + S^{2-} \rightleftharpoons CuS$

9. Iron(II) Ion, Fe^{2+}

$Fe^{2+} + CO_3^{2-} \rightleftharpoons FeCO_3$

$Fe^{2+} + 2OH^- \rightleftharpoons Fe(OH)_2$

$Fe(OH)_2 + 6CN^- \rightleftharpoons [Fe(CN)_6]^{4-} + 2OH^-$

$FeCO_3 + 6CN^- \rightleftharpoons [Fe(CN)_6]^{4-} + CO_3^{2-}$

$Fe^{2+} + S^{2-} \rightleftharpoons FeS$

10. Iron (III) Ion, Fe^{3+}

$Fe^{3+} + AsO_4^{3-} \rightleftharpoons FeAsO_4$

$Fe^{3+} + 6CN^- \rightleftharpoons [Fe(CN)_6]^{3-}$

$Fe^{3+} + 6F^- \rightleftharpoons [FeF_6]^{3-}$

$Fe^{3+} + 3OH^- \rightleftharpoons Fe(OH)_3$

$Fe^{3+} + PO_4^{3-} \rightleftharpoons FePO_4$

$Fe^{3+} + SCN^- \rightleftharpoons [Fe(SCN)]^{2+}$

$2Fe^{3+} + 3S^{2-} \rightleftharpoons Fe_2S_3$

11. Mercury (II) Ion, Hg^{2+}

$Hg^{2+} + 4Br^- \rightleftharpoons [HgBr_4]^{2-}$

$Hg^{2+} + 4Cl^- \rightleftharpoons [HgCl_4]^{2-}$

$Hg^{2+} + 2I^- \rightleftharpoons HgI_2$

$HgI_2 + 2I^- \rightleftharpoons [HgI_4]^{2-}$

$Hg^{2+} + 2OH^- \rightleftharpoons HgO + H_2O$

$HgO + H_2O + 4Br^- \rightleftharpoons [HgBr_4]^{2-} + 2OH^-$
$HgO + H_2O + 4Cl^- \rightleftharpoons [HgCl_4]^{2-} + 2OH^-$
$HgO + H_2O + 4I^- \rightleftharpoons [HgI_4]^{2-} + 2OH^-$
$Hg^{2+} + 4SCN^- \rightleftharpoons [Hg(SCN)_4]^{2-}$
$HgO + H_2O + 4SCN^- \rightleftharpoons [Hg(SCN)_4]^{2-} + 2OH^-$
$Hg^{2+} + 4CN^- \rightleftharpoons [Hg(CN)_4]^{2-}$
$HgO + H_2O + 4CN^- \rightleftharpoons [Hg(CN)_4]^{2-} + 2OH^-$
$Hg^{2+} + S^{2-} \rightleftharpoons HgS$
$[Hg(CN)_4]^{2-} + S^{2-} \rightleftharpoons HgS + 4CN^-$
$[HgBr_4]^{2-} + S^{2-} \rightleftharpoons HgS + 4Br^-$
$[HgCl_4]^{2-} + S^{2-} \rightleftharpoons HgS + 4Cl^-$
$[Hg(SCN)_4]^{2-} + S^{2-} \rightleftharpoons HgS + 4SCN^-$

12. <u>Magnesium Ion, Mg^{2+}</u>

$3Mg^{2+} + 2AsO_4^{3-} \rightleftharpoons Mg_3(AsO_4)_2$
$Mg^{2+} + CO_3^{2-} \rightleftharpoons MgCO_3$
$Mg^{2+} + 2F^- \rightleftharpoons MgF_2$
$Mg^{2+} + 2OH^- \rightleftharpoons Mg(OH)_2$

13. <u>Manganese (II) Ion, Mn^{2+}</u>

$3Mn^{2+} + 2AsO_4^{3-} \rightleftharpoons Mn_3(AsO_4)_2$
$Mn^{2+} + CO_3^{2-} \rightleftharpoons MnCO_3$
$Mn^{2+} + 2OH^- \rightleftharpoons Mn(OH)_2$
$Mn^{2+} + S^{2-} \rightleftharpoons MnS$

14. <u>Nickel (II) Ion, Ni^{2+}</u>

$3Ni^{2+} + 2AsO_4^{3-} \rightleftharpoons Ni_3(AsO_4)_2$
$Ni_3(AsO_4)_2 + 12CN^- \rightleftharpoons 3[Ni(CN)_4]^{2-} + 2AsO_4^{3-}$
$Ni^{2+} + 4CN^- \rightleftharpoons [Ni(CN)_4]^{2-}$
$Ni^{2+} + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+}$
$Ni^{2+} + 2OH^- \rightleftharpoons Ni(OH)_2$
$Ni(OH)_2 + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+} + 2OH^-$
$Ni(OH)_2 + 4CN^- \rightleftharpoons [Ni(CN)_4]^{2-} + 2OH^-$
$Ni^{2+} + S^{2-} \rightleftharpoons NiS$
$NiCO_3 + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+} + CO_3^{2-}$
$NiCO_3 + 4CN^- \rightleftharpoons [Ni(CN)_4]^{2-} + CO_3^{2-}$
$[Ni(CN)_4]^{2-} + S^{2-} \rightleftharpoons NiS + 4CN^-$
$[Ni(NH_3)_6]^{2+} + S^{2-} \rightleftharpoons NiS + 6NH_3$

15. Lead (II) Ion, Pb^{2+}

$Pb^{2+} + 2Br^- \rightleftharpoons PbBr_2$
$Pb^{2+} + 2Cl^- \rightleftharpoons PbCl_2$
$Pb^{2+} + 2F^- \rightleftharpoons PbF_2$
$Pb^{2+} + CO_3^{2-} \rightleftharpoons PbCO_3$
$Pb^{2+} + CrO_4^{2-} \rightleftharpoons PbCrO_4$
$3Pb^{2+} + 2PO_4^{3-} \rightleftharpoons Pb_3(PO_4)_2$
$Pb^{2+} + 2I^- \rightleftharpoons PbI_2$
$PbI_2 + 2I^- \rightleftharpoons [PbI_4]^{2-}$
$Pb^{2+} + 4I^- \rightleftharpoons [PbI_4]^{2-}$
$Pb_3(PO_4)_2 + 12I^- \rightleftharpoons 3[PbI_4]^{2-} + 2PO_4^{3-}$
$Pb^{2+} + 2OH^- \rightleftharpoons Pb(OH)_2$
$Pb(OH)_2 + 2OH^- \rightleftharpoons [Pb(OH)_4]^{2-}$
$Pb^{2+} + 4OH^- \rightleftharpoons [Pb(OH)_4]^{2-}$
$Pb^{2+} + 2SCN^- \rightleftharpoons Pb(SCN)_2$
$Pb^{2+} + SO_4^{2-} \rightleftharpoons PbSO_4$
$Pb^{2+} + S^{2-} \rightleftharpoons PbS$
$[PbI_4]^{2-} + S^{2-} \rightleftharpoons PbS + 4I^-$
$[PbI_4]^{2-} + SO_4^{2-} \rightleftharpoons PbSO_4 + 4I^-$

16. Strontium Ion, Sr^{2+}

$3Sr^{2+} + 2AsO_4^{3-} \rightleftharpoons Sr_3(AsO_4)_2$
$Sr^{2+} + CO_3^{2-} \rightleftharpoons SrCO_3$
$Sr^{2+} + CrO_4^{2-} \rightleftharpoons SrCrO_4$
$Sr^{2+} + SO_4^{2-} \rightleftharpoons SrSO_4$
$3Sr^{2+} + 2PO_4^{3-} \rightleftharpoons Sr_3(PO_4)_2$

17. Zinc Ion, Zn^{2+}

$3Zn^{2+} + 2AsO_4^{3-} \rightleftharpoons Zn_3(AsO_4)_2$
$Zn^{2+} + CO_3^{2-} \rightleftharpoons ZnCO_3$
$Zn^{2+} + 2CN^- \rightleftharpoons Zn(CN)_2$
$Zn^{2+} + 4NH_3 \rightleftharpoons [Zn(NH_3)_4]^{2+}$
$Zn^{2+} + 2OH^- \rightleftharpoons Zn(OH)_2$
$Zn(OH)_2 + 2OH^- \rightleftharpoons [Zn(OH)_4]^{2-}$
$Zn^{2+} + 4OH^- \rightleftharpoons [Zn(OH)_4]^{2-}$
$[Zn(OH)_4]^{2-} + S^{2-} \rightleftharpoons ZnS + 4OH^-$
$Zn^{2+} + S^{2-} \rightleftharpoons ZnS$

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$$[Zn(NH_3)_4]^{2+} + S^{2-} \rightleftharpoons ZnS + 4NH_3$$

$$3Zn^{2+} + 2PO_4^{3-} \rightleftharpoons Zn_3(PO_4)_2$$

I. SOLUBILITY PRODUCTS

Arsenates

Ag_3AsO_4	1.0×10^{-21}	$Cu_3(AsO_4)_2$	7.6×10^{-36}
$AlAsO_4$	1.5×10^{-16}	$FeAsO_4$	5.8×10^{-21}
$Ba_3(AsO_4)_2$	7.8×10^{-51}	$Mg_3(AsO_4)_2$	2.1×10^{-20}
$Ca_3(AsO_4)_2$	6.8×10^{-19}	$Mn_3(AsO_4)_2$	1.9×10^{-29}
$Cd_3(AsO_4)_2$	2.7×10^{-33}	$Ni_3(AsO_4)_2$	4.1×10^{-36}
$Co_3(AsO_4)_2$	7.6×10^{-29}	$Sr_3(AsO_4)_2$	1.3×10^{-18}
$CrAsO_4$	7.8×10^{-21}	$Zn_3(AsO_4)_2$	1.0×10^{-28}

Bromides

$AgBr$	4.9×10^{-13}	$PbBr_2$	2.8×10^{-5}

Carbonates

Ag_2CO_3	5.6×10^{-12}	$NiCO_3$	6.6×10^{-9}
$BaCO_3$	5.1×10^{-9}	$PbCO_3$	6×10^{-14}
$CaCO_3$	7.2×10^{-9}	$SrCO_3$	4×10^{-10}
$CdCO_3$	5×10^{-9}	$ZnCO_3$	1.4×10^{-11}
$FeCO_3$	3.5×10^{-11}	$CoCO_3$	8×10^{-13}
$MgCO_3$	$3. \times 10^{-5}$	$CuCO_3$	2.5×10^{-10}
$MnCO_3$	4×10^{-11}		

Chlorides

$AgCl$	1.78×10^{-10}	$PbCl_2$	1×10^{-4}

Chromates

Ag_2CrO_4	1.2×10^{-12}	$PbCrO_4$	1.7×10^{-14}
$BaCrO_4$	1.1×10^{-10}	$SrCrO_4$	3.6×10^{-5}
$CuCrO_4$	4.9×10^{-6}		

Cyanides

$AgCN$	1.2×10^{-16}	$Zn(CN)_2$	$3. \times 10^{-8}$

Fluorides

BaF_2	1.0×10^{-6}	PbF_2	3.1×10^{-8}
CaF_2	3.9×10^{-11}	SrF_2	2.7×10^{-9}
MgF_2	6.5×10^{-9}		

Hydroxides

$AgOH$	1.0×10^{-8} *)	$Fe(OH)_3$	3.2×10^{-38}
$Al(OH)_3$	2×10^{-32}	$Hg(OH)_2$	6×10^{-26} **)
$Cd(OH)_2$	6×10^{-15}	$Mg(OH)_2$	1.1×10^{-11}
$Co(OH)_2$	6×10^{-15}	$Mn(OH)_2$	4.5×10^{-13}
$Cr(OH)_3$	8×10^{-31}	$Ni(OH)_2$	2×10^{-15}
$Cu(OH)_2$	3×10^{-20}	$Pb(OH)_2$	1.6×10^{-20}
$Fe(OH)_2$	8×10^{-16}	$Zn(OH)_2$	1×10^{-16}

*) Must be interpreted as $\frac{1}{2}Ag_2O + \frac{1}{2}H_2O \rightleftharpoons Ag^+ + OH^-$

**) Must be interpreted as $HgO + H_2O \rightleftharpoons Hg^{2+} + 2OH^-$

Iodides

AgI	9.8×10^{-17}	PbI_2	1.0×10^{-9}
HgI_2	1.0×10^{-28}		

Phosphates

Ag_3PO_4	1.2×10^{-20}	$CrPO_4$	1.0×10^{-17}
$AlPO_4$	7.2×10^{-19}	$FePO_4$	1.2×10^{-22}
$Ba_3(PO_4)_2$	6×10^{-39}	$Pb_3(PO_4)_2$	1.0×10^{-44}
$Ca_3(PO_4)_2$	1.0×10^{-28}	$Sr_3(PO_4)_2$	1×10^{-31}

Sulphates

Ag_2SO_4	1.7×10^{-5}	$PbSO_4$	1.7×10^{-8}
$BaSO_4$	1.0×10^{-10}	$SrSO_4$	3.2×10^{-7}
$CaSO_4$	1.2×10^{-6}		

Sulphides

Ag_2S	1.1×10^{-49}	HgS	8.6×10^{-52}
CdS	7.8×10^{-27}	MnS	5.1×10^{-15}
CoS	5.9×10^{-21}	NiS	1.8×10^{-21}
CuS	8.7×10^{-36}	PbS	8.4×10^{-28}
FeS	4.9×10^{-18}	ZnS	1.1×10^{-21}
Fe_2S_3	1.4×10^{-35}		

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Thiocyanates

AgSCN	1.0×10^{-12}	$Pb(SCN)_2$	2.0×10^{-5}

II. INSTABILITY CONSTANTS

Instability Constants of Complex Ions

$[AlF_6]^{3-}$	1.5×10^{-20}	$[HgBr_4]^{2-}$	2.3×10^{-22}
$[Cd(NH_3)_4]^{2+}$	1.0×10^{-7}	$[HgCl_4]^{2-}$	1×10^{-16}
$[Cd(CN)_4]^{2-}$	1.0×10^{-19}	$[Hg(SCN)_4]^{2-}$	5×10^{-20}
$[Co(NH_3)_6]^{2+}$	1.2×10^{-5}	$[Ni(NH_3)_6]^{2+}$	1.8×10^{-9}
$[Cu(NH_3)_4]^{2+}$	5×10^{-15}	$[Ni(CN)_4]^{2-}$	1×10^{-22}
$[Fe(CN)_6]^{4-}$	1×10^{-35}	$[Ag(NH_3)_2]^{+}$	6.8×10^{-8}
$[Fe(CN)_6]^{3-}$	1×10^{-42}	$[Ag(CN)_2]^{-}$	1.8×10^{-19}
$[FeF_6]^{3-}$	1×10^{-16}	$[Zn(NH_3)_4]^{2+}$	3.4×10^{-10}
$[FeSCN]^{2+}$	1×10^{-3}	$[Zn(CN)_4]^{2-}$	1×10^{-18}
$[PbI_4]^{2-}$	3.6×10^{-6}	$[Al(OH)_4]^{-}$	2×10^{-2}
$[PbBr_4]^{2-}$	1×10^{-13}	$[Cr(OH)_4]^{-}$	1×10^{2}
$[Hg(CN)_4]^{2-}$	4×10^{-42}	$[Zn(OH)_4]^{2-}$	1×10
$[HgI_4]^{2-}$	5×10^{-31}		

Conclusion

Chemistry teachers can work together with their students in making packs(s) of cards. It will help the students if every class-room is equipped with tables, diagram, and figures (including the colours of precipitates and complex ions) These can be done as extra-curricular activities. The game can also be played by 2,3 or 4 groups of students. If there are more than one pack of cards available, competition among the groups is quite possible. (Which group can collect the highest points). Chemistry kits can be made very simple. By using semi-micro test tubes, students can use the solutions more economically.

Chemistry card game can be used as visual aid in teaching some types of reaction. By using all kinds of symbols usually used in chemistry processes, it is possible to make several kinds of packs of cards according to the needs (oxidation-reduction, neutralizations, metathetic reactions, even inorganic and organic syntheses, and nuclear chemistry). Let us try to improve this scientific game.

ABOUT THE KIT

The kit is set-up to accompany Chemistry Card Game. As has been mentioned, the kit is provided for students to do some practical works. Chemistry teachers can also use the kit for many purposes, e.g. (1) to carry out some experiments other than stated in "Reaction Equations", in trying to improve the effectiveness of using the cards. (2) to demonstrate some of the reactions as illustrations for the whole class.

We also hope that, the "simple kit" we suggest here can stimulate and encourage our chemistry teachers to set-up other types of such kits for accompanying other types of Chemistry Card Games.

The kit is made of wood (1 cm thickness), the inner dimensions are 24 cm x 32 cm x 17½ cm. The kit is devided into 2 compartments: one for chemicals, and the other one for apparatus.

Requirements

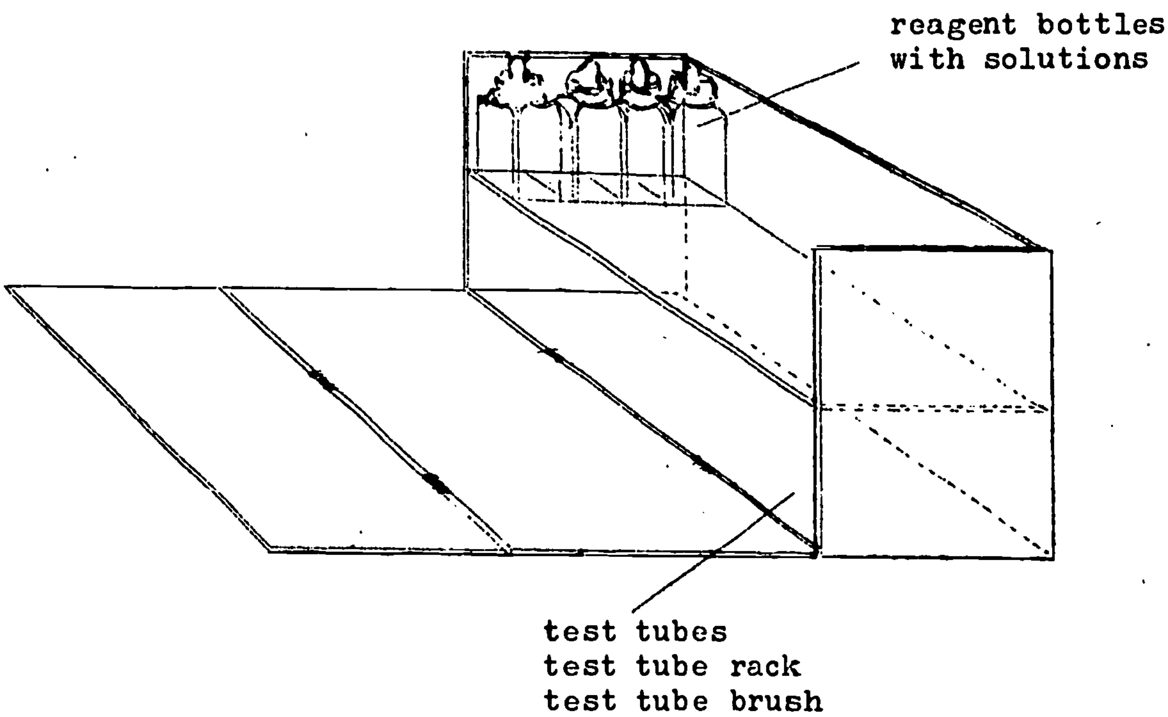
32 reagent bottles, 50 ml in capacity (square bottles with droppers)
20 semi-micro test-tubes, 1 cm x 8 cm
1 test-tube rack
1 test-tube brush
32 kinds of 0.1M solutions (see footnotes) i.e.

	Names of Chemicals	Ions/molecule
1.	Aluminium chloride, $AlCl_3.6H_2O$	Al^{3+}
2.	Aqueous ammonia, NH_3	NH_3 *)
3.	Barium chloride, $BaCl_2.2H_2O$	Ba^{2+}
4.	Cadmium nitrate, $Cd(NO_3)_2.4H_2O$	Cd^{2+}
5.	Calcium chloride, $CaCl_2.6H_2O$	Cd^{2+}
6.	Chromium(III) sulphate, $Cr_2(SO_4)_3.18H_2O$	Cr^{3+}
7.	Cobalt(II) sulphate, $CoSO_4.7H_2O$	Co^{2+}
8.	Copper(II) sulphate, $CuSO_4.5H_2O$	Cu^{2+}
9.	Iron(II) ammonium sulphate, $FeSO_4(NH_4)_2SO_4.6H_2O$	Fe^{2+}
10.	Iron(III) ammonium sulphate, $Fe_2(SO_4)_3(NH_4)_2SO_4.24H_2O$	Fe^{3+}
11.	Lead acetate, $Pb(CH_3COO)_2$	Pb^{2+}
12.	Magnesium chloride , $MgCl_2$	Mg^{2+}
13.	Manganese(II) sulphate, $MnSO_4$	Mn^{2+}
14.	Mercury(II) nitrate, $Hg(NO_3)_2.H_2O$	Hg^{2+}
15.	Nickel(II) sulphate, $NiSO_4.7H_2O$	Ni^{2+}
16.	Potassium bromide, KBr	Br^-
17	Potassium chromate, K_2CrO_4	CrO_4^{2-}
18.	Potassium iodide, KI	K^+, I^-
19.	Silver nitrate, $AgNO_3$	Ag^+
20.	Sodium arsenate, $Na_3AsO_4.12H_2O$	AsO_4^{3-}
21.	Sodium carbonate, $Na_2CO_3.10H_2O$	CO_3^{2-}
22.	Sodium chloride, NaCl	Cl^-
23.	Sodium cyanide, NaCN	CN^-
24.	Sodium fluoride, NaF	F^-
25.	Sodium hydroxide, NaOH	OH^- **)

*) 1.5M NH_3 is used in our experiments.
**) 1.0M NaOH is used in our experiments.

26. Sodium nitrate, $NaNO_3$ — NO_3^-
27. Sodium phosphate, $Na_3PO_4 \cdot 10H_2O$ — PO_4^{3-}
28. Sodium sulphate, $Na_2SO_4 \cdot 10H_2O$ — Na^+, SO_4^{2-}
29. Sodium sulphide, $Na_2S \cdot 9H_2O$ — S^{2-}
30. Sodium thiocyanate, NaSCN — SCN^-
31. Strontium chloride, $SrCl_2 \cdot 2H_2O$ — Sr^{2+}
32. Zinc chloride, $ZnCl_2$ — Zn^{2+}

Design



This simple kit does not cost too much. According to our calculation, the complete set costs about $7.50. Every High School can modify the type, and use local materials to lower the price.

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Announcement

In order to support experimental work at schools, the Editors of this Newsletter are asking individuals or institutions to submit to us articles about low-cost chemistry teaching experiments. The length of the articles should not be more than 10 single-typed pages and should contain sufficient detail for the experiment to be repeated, preferably with graphs and diagrams of the equipments (no photographs). The submitted articles should have originality and deal with important topics of chemistry. However, modified experiments or sets of experiments of published work will be accepted provided that reference to the original work is cited and a clear explanation of the modification is given. Included in the article must be an estimate of the cost of the experiment. The deadline for submitting the article is 31st December 1969. All relevant articles submitted will be published in the Newsletter. The Editors will decide on the most suitable experiment and the winner will be awarded with a set of the recent edition of Chem Study materials.

A PRACTICAL LESSON ON OXYGEN

by

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The following is an alaptation of an O-Level Nuffield Chemistry Stage I experiment. It has been tried out among five groups of in-service teachers of some 25 participants per group. The participants worked in pairs, but enough time and materials were given to enable each participant to try out each experiment for himself until he was satisfied. The author hopes to conduct further adaptations of Nuffield O-Level Chemistry in the light of the Singapore context.

Preliminary Demonstrations for a Teachers' Course.

This portion may be omitted when we are carrying out experiments with school pupils. However for a teachers' course I believe the following demonstrations would help the teachers very much to be aware of the hazards of the chemistry laboratory and thereby avert serious accidents.

1. Heat a little of potassium chlorate with manganese dioxide in a test tube. A glowing splinter which is often used to test for oxygen is now slowly inserted until it touches the hot chlorate - manganese dioxide mixture. Note the violence of the reaction. A few unknowing school pupils do this - quite often with unhappy endings.

2. Heat a test tube full of roughly equal amounts of chlorate and powdered charcoal. Note again the violence of the reaction - rather reminiscent of New Year's fireworks. Demonstration No. 2 which we may term "accident-on-purpose" is significant. Quite often manganese dioxide is contaminated with carbonaceous material, or worse still due to mislabelling it might be powdered carbon itself. After all both manganese dioxide and powdered carbon are black and you can't tell them apart - by appearance that is.

So the moral of the story is if you want to prepare oxygen by the chlorate-manganese dioxide method, test a little of the mixture first before doing it on a large scale or handing it over to the pupils. The demonstration had better be done behind a safety screen or at least 5 feet away from the participants, taking the precaution not to point the mouth of the test tubes at anyone.

More Specific Remarks concerning the Experiments

The main idea is of course that the pupils should experiment as far as possible. For that matter all operations are reduced to small scale. Pupils really learn when they handle apparatus and materials (a platitude but often overlooked). Of course there are

certain limitations to this freedom to experiment. The burning of yellow phosphorus, sodium, carries with it a certain amount of danger and it had better be done as a teacher demonstration.

Although one does not like to condemn the potassium chlorate-manganese dioxide reaction for preparation of oxygen despite the disadvantages discussed, one must admit it is a little too well known. <u>A rather efficient method employs the catalytic decomposition of hydrogen peroxide.</u>

$$2H_2O_2 \xrightarrow{MnO_2} 2H_2O + O_2$$

No heating is necessary. The oxygen gas is readily evolved.

Some teachers may like to make use of the reaction between hydrogen peroxide and potassium permanganate. However the equation tends to be too cumbersome for elementary forms.

It is a good idea to have an oxygen generator of the type ready on the teacher's bench (Fig. 1.)

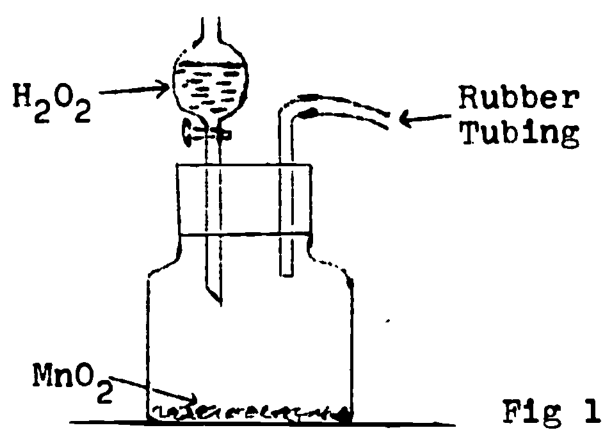


Fig 1.

In case some pupils experience difficulties with their experiments e.g. burning of steel wool, they could come up and the teacher could then show them the correct techniques of carrying out the experiment.

<u>Approximate Requirements for Pair of Pupils</u>

1 Hard glass boiling tube 150 x 25 mm.

1 Test tube rack

5 - 6 Medium sized (150 x 15 mm) test tubes.

Clothes-line wire about 9" length.

Bunsen burner, asbestos square

Glass rod

Teat pippete

Small pieces of charcoal

Steel wool

Magnesium ribbon

Powdered sulphur

Fresh lime-water

Universal indicator solution.

Diagram and Procedure

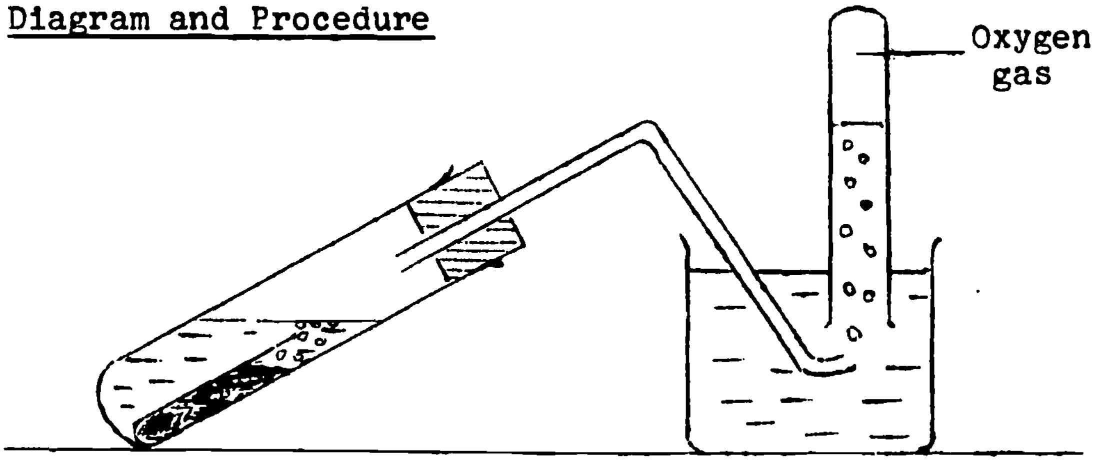
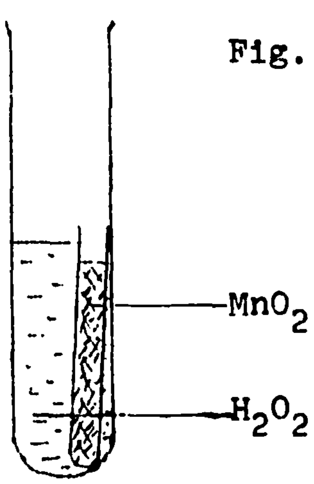


Fig. 2

The purpose of the capsule is to control the rate of reaction. When the reaction slows down pupils can agitate the boiling tube occasionally. In case the peroxide is exhausted the liquid may be decanted and fresh peroxide solution added.

Fig. 3



In filling up the boiling tube it is good to have the level of the liquid peroxide just a little below the level of the small capsule (Fig. 3). It is good to arrange a 600 ml. beaker at or near the sink, so that during the collection of gas the overflow of water will not wet pupils' benches. Five or six medium sized test-tubes may be completely filled with water closed with the thumb and inverted in the beaker. <u>All these preparations will have to be made before the reaction is allowed to commence.</u> Let the first few bubbles escape. Then collect the gas as shown (Fig. 2). It is not necessary to stopper the gas. One pupil can help to hold the test-tube inverted with the open end immersed in water. Collect a total of 5-6 test-tubes.

Pupils may now proceed to burn substances in oxygen. Hold the test tube of gas closed with the thumb. Only remove the thumb when the burning element is ready to be inserted.

Combustion of the following elements are carried out

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(a) Carbon :

Make sure the size of the charcoal piece is such that it can slide conveniently into the mouth of the test-tube. If not, chip it off accordingly. Then tie the end of a wire round the charcoal piece. Heat the charcoal in the Bunsen flame and push it into a test tube of oxygen gas.

After the combustion, test for carbon dioxide. Withdraw the gas from reaction vessel by means of a clean teat-pipette and bubble it into a test tube of fresh clear lime-water.

(b) Sulphur :

Warm up the tip of a glass rod. Allow the hot end to touch and pick up a little sulphur powder. Bring the sulphur to the flame and when it is burning slightly push it into a test-tube of oxygen as before.

(c) Iron :

Steel wool is found to work much better than iron filings. Again wrap a little steel wool round one end of the wire. Bring it to the flame and when it begins to glow push it into a test-tube of oxygen.

If the experiment does not work it may be due to a strong draught (from the ceiling fan perhaps, which tends to cool the iron). The reaction is more spectacular if a boiling tube of oxygen gas were used.

(d) Magnesium :

The magnesium piece could be held at the end of a wire and burnt as previously.

Is there any difference between burning these substances in air and in oxygen?

After the combustion is over the residue of the test-tube could be tested with Universal Indicator. This could be handed out in a diluted form or more economically in the form of paper strips.

Comments on Experiments with Reference to Nuffield.

(a) The stress is on pupils' own experiment as in the Nuffield scheme.

(b) Oxygen cylinders are not readily available in Singapore schools. The reaction used is the same as the one suggested in Nuffield is the same viz. the catalytic decomposition of hydrogen peroxide by manganese dioxide. The apparatus used however has been modified. Instead of the thistle funnel a tap-funnel is recommended. This enables the addition of hydrogen peroxide to be carried out even drop by drop. For the pupils experiment the 'capsule' method

of holding the manganese dioxide is recommended.

(c) Gases are collected mainly in medium sized test-tubes as against collection in boiling tubes in Nuffield. No corks are used. Pupils are asked to hold the test tubes inverted in water.

(d) The technique of burning substances are modified. No combustion spoons are used. The tip of the glass rod is used in burning the sulphur. A length of metal wire is used for support of substances during combustion.

(e) The use of the teat pipette as suggested in the Nuffield scheme is an excellent idea.

(f) The idea of using Universal Indicator and introducing the simple concept of pH is a very good one.

Increased Acidity		Increased Alkalinity
←		→
0	7	14
very acidic	neutral	very alkaline

(g) The discussion of the simple ideas of metals and non-metals and simple classification of elements arising from the experiments is most relevant and should be retained.

(h) The burning of substances like sodium, phosphorus which Nuffield does not seem to have mentioned is hereby suggested for teachers demonstration.

My grateful acknowledgements to the following for their kind assistance and encouragement.

1. Dr. G. Van Praagh and Mr. B.J. Stokes of the Nuffield Team.
2. Mr. C.S. Chung of Raffles Institution, Singapore.

Displacement Reaction

between Ag_2CrO_4 and KI

by

Sjarifuddin B. Hosen

Displacement reactions are quite familiar to our High School students. In this article we are going to show to the readers that simple displacement reaction can be carried out in our schools for students' experimentation.

In the Project laboratory we were studying the reaction between solid silver chromate and potassium iodide solution, by using broken burette as column. We studied both qualitative and quantitative aspects. The reaction is simple:

$$Ag_2CrO_4 + 2KI \longrightarrow 2AgI + K_2CrO_4\text{, or}$$

$$Ag_2CrO_4 + 2I^- \longrightarrow 2AgI + CrO_4^{2-} \quad \text{------------(1)}$$

The changes of colours are very easy observed:

$$\underset{\text{reddish brown}}{Ag_2CrO_4} \longrightarrow \underset{\text{yellow}}{AgI}$$

$$\underset{\text{colourless}}{I^-} \longrightarrow \underset{\text{yellow}}{CrO_4^{2-}}$$

The question is: does reaction (1) proceed quantitatively? To answer this question we have to determine iodide ion concentration by indirect method, it means, by determining CrO_4^{2-} ions liberated during the reaction, and then compare the result with standard solution.

The procedure is as follows: change the CrO_4^{2-} into $Cr_2O_7^{2-}$, and determine the $Cr_2O_7^{2-}$ iodometrically.

$$\underset{\text{yellow}}{2CrO_4^{2-}} + 2H^+ \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}} + H_2O \quad \text{------------(2)}$$

$$Cr_2O_7^{2-} + 14H^+ + 6I^- \rightleftharpoons 2Cr^{3+} + 7H_2O + 3I_2 \quad \text{------------(3)}$$

$$I_2 + 2S_2O_3^{2-} \rightleftharpoons S_4O_6^{2-} + 2I^- \quad \text{------------(4)}$$

By using known molarity of sodium thiosulphate solution to react with I_2 (eq.(4)) liberated in eq. (3), we can calculate the concentration of $Cr_2O_7^{2-}$ ions, and from this through eq. (2) and eq. (1) to calculate the I^- ion concentration.

Instead of shaking Ag_2CrO_4 with the solution of KI to be tested, and in order to avoid filtering and washing of the suspension after the treatment, we have modified the method by using a column of Ag_2CrO_4 placed in the broken burette, and passing through the solution of KI.

Experiement

Requirements:

Dry silver chromate (see note 1)
Potassium iodide solution, 0.1M
Sodium thiosulphate solution, 0.1M
Starch solution, 1%
Sulphuric Acid, 2M

2 Broken burettes, approx. 25 ml in capacity (loosely plugged with cotton wool), used as columns.
2 Conical flasks, 150 ml
2 Burettes, 50 ml
Washing bottle, with distilled water
Metallic spatula
Burette holders
Balance, analytical

Procedure

1. Weigh out 2 portions of Ag_2CrO_4, each about 1.5 g. Pour each portion into each column, by using the spatula. It must be done very careful to avoid adherence of the solid to the upper wall of the columns.

2. By using a burette, pour 10.00 ml KI to each of the columns. Let the mixture stand for 10 minutes before draining.

3. Open the taps and collect the eluent into the flask. Rates of flow must be approximately the same (in about 3 minutes the liquid will be drained off). Rinse the columns by using 10.00 ml. distilled water, and collect into the same flask. Observe that the last drop is colourless.

4. Add 5 ml H_2SO_4 to each of the flasks, then shake the mixture thoroughly. Observe the change of colour from yellow to orange. Add another 2.5 ml H_2SO_4 to acidify the solutions. Allow the solutions to cool to room temperature.

5. Add KI solution in excess (concentrated solution is preferred) to each flask just before the titration is carried out. Allow the brown solution to stand for 1 minute and then titrate with standard solution of $Na_2S_2O_3$ till the solution is pale yellow. Then add 1 ml of starch as indicator and complete the titration.

6. The end-point is reached when the blue solution turns colourless.

Carry out a blank experiment, using distilled water (use same volume as the volume of KI solution). Deduct the volume of $Na_2S_2O_3$ consumed in the blank experiment from the volume of $Na_2S_2O_3$ solution consumed in the experiment, before

calculating the result.

Results

Column I		Column II	
KI	$Na_2S_2O_3$	KI	$Na_2S_2O_3$
10.00 ml	15.06 ml	10.00 ml	14.6[illegible] ml

Chemical Equations and Calculations

$$Ag_2CrO_4 + 2KI \longrightarrow 2AgI + K_2CrO_4$$

$$Ag_2CrO_4 + 2I^- \longrightarrow 2AgI + CrO_4^{2-} \quad \text{------(1)}$$

$$2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O \quad \text{------(2)}$$

After adding excess I^-

$$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O \quad \text{------(3)}$$

$$2I^- \rightleftharpoons I_2 + 2e \quad \text{------(4)}$$

Summing up (3) and 3x(4) we get:

$$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$$

$$6I^- \rightleftharpoons 3I_2 + 6e$$

$$Cr_2O_7^{2-} + 14H^+ + 6I^- \rightleftharpoons 2Cr^{3+} + 7H_2O + 3I_2 \quad \text{---(5)}$$

After titrating with $Na_2S_2O_3$

$$I_2 + 2e \rightleftharpoons 2I^- \quad \text{--------(6)}$$

$$2S_2O_3^{2-} \rightleftharpoons S_4O_6^{2-} + 2e \quad \text{--------(7)}$$

Summing up (6) and (7) we get:

$$2S_2O_3^{2-} + I_2 \rightleftharpoons S_4O_6^{2-} + 2I^- \quad \text{--------(8)}$$

Column 1 0.1M $S_2O_3^{2-}$ used is 15.06 ml.
From eq.(8) 2 moles of $S_2O_3^{2-}$ react with 1 mole of I_2.
The molarity of I_2 is $\frac{15.06}{10} \times 0.1 \times \frac{1}{2}$ (10 ml is the volume of KI used)

From eq.(5) there are 3 moles of I_2 liberated from 1 mole of $Cr_2O_7^{2-}$
molarity of $Cr_2O_7^{2-}$ is $\frac{15.06}{10} \times 0.1 \times \frac{1}{2} \times \frac{1}{3}$

It can be seen from eq.(2)and(1)that 4 moles of iodide are equivalent to 1 mole of $Cr_2O_7^{2-}$, so the molarity of the iodide solution used is $\frac{15.06}{10} \times 0.1 \times \frac{1}{2} \times \frac{1}{3} \times 4$

$$= 0.1004 \text{ M}$$

Column 2 Similarly, molarity of iodide solution is $\frac{14.68}{10} \times 0.1 \times \frac{1}{2} \times \frac{1}{3} \times 4$

$$= 0.0979 \text{ M}$$

Discussion

According to the results, the errors are

Column I $\frac{0.0004}{0.1000} \times 100\% = 0.4\%$

Column II $\frac{0.0021}{0.1000} \times 100\% = 2.1\%$

For school experimentations those errors are acceptable. From chemistry teaching point of view this experiment is quite interesting. The preparation of Ag_2CrO_4 can be given as students' assignment; the column is easy to arrange, and the experiment can be done, relatively, in a short period.

Two laboratory-hours, are more than sufficient to carry out the experiment, except for preparing Ag_2CrO_4.

Notes:

1. Silver chromate, Ag_2CrO_4, is prepared by mixing silver nitrate solution, $AgNO_3$, and potassium chromate solution, K_2CrO_4. By using the same strength of these solutions, students can learn the stoichiometry of the reaction. The precipitate is washed several times with distilled water, and then filtered. Dry over-night in an oven, at 110°C. Preparing 10 - 15 g. is quite sufficient; the solid is stable and can be kept for a long time.

$$2AgNO_3 + K_2CrO_4 \longrightarrow Ag_2CrO_4 + 2KNO_3$$

2. By using exact weight of Ag_2CrO_4, students can also determine the solubility of Ag_2CrO_4, in water. This can be done while carrying out blank experiment.

3. This displacement reaction experiment has been done several times in the Project Laboratory. The blank experiment has also been carried out, and the result is that $Na_2S_2O_3$ used to titrate the eluent is practically negligible (usually 0.02 ml 0.1M $Na_2S_2O_3$ for titrating 10 ml eluent passed through about 1.5 g. Ag_2CrO_4).

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4. The method is based on the different solubility products of Ag_2CrO_4 and AgI.

$$K_s = [Ag^+]^2 \, [CrO_4^{2-}] = 1.29 \times 10^{-12}$$

$$K_s = [Ag^+][I^-] = 9.8 \times 10^{-17}$$

We come to the conclusion that, CrO_4^{2-} is quantitatively displaced by I^-.

5. This experiment is suggested to be included in the school laboratory experiments, not to replace the argentometric titration methods, but just to add the variations of determining I^- quantitively.

6. The experiment will also show to the students how the sensitivity of a determination can be increased. In determining iodides argentometrically, the reactants react in the ratio 1:1, but this is not the case in the above experiment. For instance, in determining 1 ml 0.1M KI argentometrically, 1 ml 0.1M $AgNO_3$ is expected to be consumed in the titration; but in determining the same volume of iodide by the above displacement reaction, 1.5 ml 0.1M $Na_2S_2O_3$ is used. This increase in volume of reagent makes the determination more accurate.

7. Similar reactions could be tested by the students, using the same principle (e.g. displacement reactions of Cl^-, Br^- with Ag_2CrO_4), using the "column" technique.

Acknowledgements

This experiment is carried out under supervision of Prof. J. Zyka

The author is indebted to Prof. J. Zyka and Dr. H. Herm for their constructive criticisms.

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Unesco Fellow, (April - October 1969)
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CURRICULUM REFORM ACTIVITIES IN OTHER AREAS

INDONESIA

THE FACULTY OF TEACHER TRAINING FOR NATURAL SCIENCES AND MATHEMATICS (F.K.I.E.) OF THE INSTITUTE OF TEACHER TRAINING AND EDUCATIONAL SCIENCES (I.K.I.P.)

In accordance with the purpose of the Institute (I.K.I.P.), namely to instruct and prepare qualified teachers for secondary schools, the curriculum of the Faculty (F.K.I.E.) is directed to the secondary school curriculum. In addition we try to keep up with the rapid development of modern science education in the world.

Our programme is divided into two parts:

1. An undergraduate programme leading to a Sardjana Muda (Bachelor's) degree which fully qualifies teachers for the junior high school.
2. A graduate programme leading to a Sardjana (Master's) degree which fully qualifies teachers for the senior high school.

The Faculty has four Departments

1. Physics Department
2. Biology Department
3. Chemistry Department
4. Mathematics Department

Besides the regular courses there are also extension courses spread throughout West Java, namely at Tasikmalaja, Bogor, Tjirebon and Sumedang.

Curriculum

An examination of the contents of the curriculum will show three groups of courses which are designed to give prospective teachers a suitable college background

1. The general courses which besides being basic courses also deal with spiritual and mental education
2. The professional courses which are vocational by nature
3. Courses in subject matter areas

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Further, the Sardjana Muda degree is awarded after completion of approximately 130 credit hours which can usually be carried in three years or six semesters. For the Sardjana degree 80 credit hours are required over a period of two years or four semesters. The proportion of credit hours divided between general/professional courses and subject matter areas is approximately 1 : 3

Teaching Staff

This academic year there are 58 staff members. Three of them have doctorate and Ph. D. degrees. Fourteen of our staff have been sent to study abroad under the auspices of the Ford Foundation, U.S.I.S., A.I.D. and grants from the Netherlands. The rest are graduated either from the I.K.I.P. or from other institutions in Indonesia.

Students

We have 349 graduate and undergraduate students. We have awarded 351 Sardjana Muda degrees to graduates who are now teaching in several high schools throughout Indonesia, and 277 Sardjana degrees to graduates who are teaching in high schools and in other I.K.I.Ps.

Forty seven students study under Government Grants and three receive grants from the Caltex Oil Company. A few years ago some of our students received grants from the Kennedy Foundation.

Activities

Our activities include teaching, staff seminars, research and service to our community.

Field trips are scheduled once a semester. Science fairs and science exhibitions are held at least once a year. We also participate in seminars and symposia concerning science education on a national as well as a regional level.

The Biology Department publishes a magazine called "FORMICA". The Chemistry Department publishes in joint cooperation with the Chemistry Study Group in Bandung "BERITA KIMIA", a bulletin on Chemistry for high school teachers.

Facilities

Laboratory

Most of our laboratory equipments can be used only for basic experiments, although some items might be appropriately used for carrying out intermediate experiments. Besides having laboratories for pure sciences, our faculty is also equipped with a laboratory for teaching science.

Some of our equipments, chemicals and teaching aids had been donated by the Ford Foundation.

Reading Materials

Most textbooks used for our courses are written in English and published abroad. To help our students to overcome the difficulties in reading and understanding the textbooks, we offer a scientific English course.

It should be mentioned that all the lectures are given in Indonesian. The English scientific terms are either adopted or translated. We have published an English - Indonesian dictionary in joint cooperation with the department for the Instruction of Mathematics and Natural Sciences.

Since not all the textbooks are easily found either in the library or in local bookstores, some of our teaching staff write mimeographs to meet students' needs.

We have received books and a few journals from foreign agencies: the Ford Foundation, USIS, UNESCO, British Council, the Netherlands Embassy. And we would like to mention that we also received personal gifts from Prof. Dr. J. Lewis, Prof. Dr. A.E. Lawrence, Prof. Dr. R. Foster, Prof. Dr. D.S. Allen.

Hopes and Wishes

1. We would like to equip our laboratory with a workshop so that students and staff may have an opportunity to make simple apparatus and other teaching aids.

2. We would like to have a University school for student teaching.

3. We would like to be supplied with new textbooks and journals.

4. We would like to work together and to exchange information with scientific institutions and teachers in other countries.

Address: FKIE - IKIP, P.O. Box 53, Bandung, Indonesia.

MALAYSIA

On Mr. Khoo Chin Hock's return to Malaysia, after spending 10 months at the UNESCO Chemistry Project, a Chemistry Study Group was formed in Penang. Its members are teachers teaching chemistry in the Upper Secondary and pre-University level.

Throughout 1967 and 1968, for two years, the Study Group met every Saturday morning at the Malayan Teachers' College in Penang from 9.00 a.m. to 11.00 a.m., except during vacations. These teachers came voluntarily to join the Study Group and it's regular meetings were held outside both normal teaching hours and extra mural activities. There were no financial gains whatsoever for the

participants. On the contrary, they had to pay for their own travelling expenses and also had to sacrifice some of their own free time. These people joined the Study Group because they want to become better chemistry teachers.

The Study Group examined materials of the following:-

(i) Cambridge Higher School Certificate "Alternative" Chemistry Syllabus.

(ii) UNESCO Pilot Project for Chemistry Teaching in Asia, and

(iii) Nuffield Chemistry Project.

The members of the Study Group are very interested to explore any new trends in Chemistry Teaching and also to devise simple and effective student experiments. They had for their references materials of the (i) C.B.A. Project and (ii) CHEM. Study Project.

The Study Group was under the supervision of Dr. Charles Wynn, a U.S. Peace Corps Volunteer, and assisted by Mr. Khoo Chin Hock. One of the main jobs was to explain the specific aims of the UNESCO Pilot Project to the other members and also to present to them the Experimental Teaching Media developed by the Project for their critical comments and adaption.

Out of the regular Saturday meetings, Dr. Wynn wrote a Teacher's Manual based on his content lectures for the new "Alternative T" Cambridge Higher School Certificate Chemistry Syllabus. The cost of production of this Manual was met by the Asia Foundation under the auspices of the Penang Association for Science Education. Copies of this Manual were sent to all Sixth Form (i.e. pre-University) schools in West Malaysia. Some of the schools have already used the Manual for at least one year and some for as long as two years. Feedback from the teachers of these schools will enable supplements to the Manual to be published from time to time and sent back to these schools for further comments and suggestions for improving the Manual.

The first Editor of this supplement was Mr. Chang Kwai who is presently attached to the Ministry of Education in Kuala Lumpur. Mr. Khoo Chin Hock is the present editor.

For 1969, the Science Department of the Malayan Teachers' College will be conducting weekend in-service courses for science teachers teaching in the lower secondary classes in and around Penang. The course will commence towards the middle of May and will last for 9 weeks.

Reported by: Mr. Khoo Chin Hock, Head of Science Department, Malayan Teachers' College, Penang, Malaysia.

NEWS NOTES

Invited by the Unesco National Study Group, Dr. Herm and Dr. Zyka contributed by lectures and laboratory courses on Electrochemistry and Chemical Equilibria, using the Project's kits, to the Summer Training Programme for Chemistry Teachers held in Manila May 5 to June 14 at the University of Santo Tomas. The success of the course proved again the efficiency of the National Study Group in the Philippines. Project's staff members were both honoured and pleased by very useful discussions with the Rector of the University of Santo Tomas, the Dean of the Faculty of Science, the Unesco National Commission for the Philippines and the Chemistry Study Group where Mrs. B. Guevara, one of the previous Project's participants, is very active. Dr. Herm used the opportunity on his way back, to stop in Phnom Penh and to start with establishing closer links between the Unesco National Commission in Cambodia and the Project.

Among numerous short term visitors, who came to the Project recently, we have to mention mainly Mr. Pardee Lowe, Educational Officer, Bureau of Educational and Cultural Affairs, Department of State, Washington, D.C., U.S.A., Dr. A. Roe, Office of International Science Activities, National Science Foundation, Washington, D.C., U.S.A., Prof. Z. Dart, Claremont, California, U.S.A. (National Science Foundation Physics Coordinator in India, Summer 1969), Dr. Bryan Stokes, Nuffield Foundation Science Teaching Project, London and Dr. G. Van Praagh, CREDO. (Curriculum Reform in Education Development Overseas), London.

Prof. J.A. Campbell, the previous Director of Chem Study Project, who is going to join, in October 1969, the Unesco Staff and the Project in Bangkok as Regional Unesco expert, stopped in Bangkok on his way to India and discussed the plans for the Project's coming year activities with Dr. E. Crunden from Unesco Regional Office for Education and with Prof. J. Zyka.

Prof. Jay A. Young, King's College, Wilkes Barre, Pennsylvania, U.S.A. spent three days with the Project in Bangkok on his way back from National Science Foundation Project in New Delhi and proceeded to Indonesia, to spend a few days with the Unesco National Study Group in Bandung.

Professor Sir Ronald S. Nyholm, University College, London, Member of the Chemistry Teaching Commission of International Union of Pure and Applied Chemistry (I.U.P.A.C.) gave a very interesting lecture on Teaching Chemistry in Great Britain and about new trends in Chemistry Teaching, at the occasion of his visit to the Project, on his way to Australia. The lecture was attended by the staff members of Chemistry Department of Chulalongkorn University, by Project's staff members, University students and teachers. A long and informal discussion was the best document of the attractiveness of the lecture.

The main topic of the discussion of Project's staff members with Dr. C. Chu, Research Director, Chemical Technology Group, Technological Research Institute, Applied Scientific Research Cooperation of Thailand, during his visit, concerned the preparation of some special reagents for fiber technology, prepared by Project's staff member upon the request for that purpose.

Dr. Sunt Techakumpuch, Project's co-director and professor of Chemistry at Chulalongkorn University, came back from his visit to the Universities in U.S.A. and Europe and is leaving again for two months to attend the course in Quantum Mechanics in Uppsala, Sweden.

Dr. R.H. Maybury, Division of Science Teaching, AVS, Unesco, Paris, attended a Conference of Chemical Societies in Rome and Prof. Zyka, who was on his way to attend the XXVth Conference of the International Union of Pure and Applied Chemistry (IUPAC) held in Cortina d' Ampezzo, Italy, was able to meet him at the airport in Rome and consult with him some recent Project's items.

Project's staff members were pleased being been able to give a brief information about the present state and a future programme to Mr. W.A.C. Mathieson (U.K.), member of Executive Board of Unesco, during his recent visit.

Dr. P.K. Chia from the University of New South Wales came for a 3-week visit to Bangkok, to join the staff and work on developing new experiments for chemistry teaching . He is on his way to State University of Florida, U.S.A. to continue with his post-doctoral research work in coordination chemistry.

Mr. E.A. Sullivan, from the same University arrived in Bangkok recently. During his three weeks stay, he will be working with the Project's staff on finalizing a set of experiments on rate of chemical reactions. He will proceed then to the University of Toronto, to continue in coordination chemistry studies.

The Project staff is lousing a very efficient coworker, Miss Kwang In Lee, who has been one year as the secretary with the Project. She is leaving for U.S.A. to continue her studies and all staff is wishing her lot of luck and success. Miss Kwang Soon Lee, her sister, is joining the Project's staff, starting August 1969 as the new secretary.

Miss Intira Hanpongpan of the College of Education, Pathumwan, who had been working previously with Mr. D. Segaller on scientific film-loops and films, came back to Bangkok after a 7-month study-trip in England on Colombo Plan Scholarship.

Dr. Herm and Prof. Zyka visited Mr. Sanan Sumitre, Under-secretary of State for Education, Ministry of Education, informed him about the present and future programme of the Project and gave him two prototype of kits on Chemical Equilibria and on Compound Formation together with other recent Project's resource materials.

Dr. R.H. Maybury, Division of Science Teaching, AVS, Unesco, Paris, came to Bangkok as the member of the U.N. mission, which is expected to finalize the request of the Thai government for a U.N. Special Fund, in order to establish in the future, the Thai Institute for Improvement of Teaching in Science and Technology. Dr. E.W. Crunden from Unesco Regional Office, Bangkok and Dr. D.G. Quirolgico, from U.N. Headquarters, New York City are the other members of the mission.

Aims and Objectives of this Project

The General Conference of Unesco, at its thirteenth session, adopted Resolution 2.122 to organize a Pilot Project for Chemistry Teaching in Asia for the purpose of initiating a fundamental re-orientation in the way of teaching chemistry through the use of modern technical devices and methodology. An agreement was signed between the Government of Thailand and Unesco on 13 July 1965 to locate the Project at Chulalongkorn University, Bangkok. The Project started as a regional project. In addition to its regional activities, the Project centre has increasingly served as a national centre for Thai science education.

The primary aim of the Project is to assist science educators in Asia in their task of carrying out reform of chemistry teaching. The Project is operating along two major lines which are distinct but co-ordinated:

1. Modernization of the chemistry courses and development of new teaching materials.
2. Assistance in carrying out in-service and pre-service teacher training, improvement of examinations and use of the latest methods of teaching.

Science educators in Asia may wish to request some or all of the following resource materials (at no cost) in sample quantities to help them carry out curriculum reform:

1. Programmed Instruction Sequence, 1966.
2. Teachers' Guide to the above programmed sequence, 1966.
3. 8 mm. Film Loops in Cassettes.*
4. Film Loop Production Notes, 1967.
5. Teachers' Guide to Film Loops, 1967
6. Compound Formation (Vols, I and II), Teachers' Digest, 1967, 1968.
7. Chemical Equilibria, A Teachers' Digest, 1968.
8. Experiments on Chemical Equilibria, 1969.
9. Experiments on Compound Formation, 1969.
10. Compound Formation Vol. 1 (Thai translation), 1969.
11. Experiments on Chemical Equilibria (Thai translation), 1969.
12. Newsletter, a bi-monthly periodical.
13. Prototypes of low cost kits:** "Teaching Experiments on Chemical Equilibria", "Teaching Experiments on Compound Formation" and "Teaching Experiments on Rate of Chemical Reactions."

* Available at a cost of U.S. $ 6.00 per film loop.
** Cannot be supplied outside Thailand.

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